DOES LAFAYETTE = NAKHLA? NOT NECESSARILY SO, BASED ON 4.2K MOSSBAUER SPECTRA OF ALL OF THE SNC METEORITES

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Introduction. In previous Mossbauer spectral studies of many of the SNC meteorites [1,2], attention was drawn to the close similarities of spectrum profiles between Lafayette [3] and Nakhla [4], which were once suggested to be identical meteorites [5]. These observations lead to the acquisition of Governador Valadares [6] and another specimen of Nakhla [7], as well as Zagami [8] and Shergotty [8,9], for Mossbauer spectral measurements at 4.2K. Results reported here demonstrate that there are subtle differences between the three nakhlites (Nakhla, Lafayette, and Governador Valadares), as there are for three of the shergottites (Shergotty, Zagami, EETA 79001/lithologies A and B) and olivine-dominated Chassigny and ALHA 77005 [2], indicating that all eight of the SNC meteorites discovered to date fell independently to Earth.

Meteorite Samples. The British Museum (Natural History) was the source of ~100 mg chips of Nakhla, Governador Valadares and Zagami, while the Mineralogical Museum at Harvard University provided samples of Nakhla. The latter specimen enabled portions to be extracted from the fresh interior and black vitreous fusion crust of the meteorite. Samples of Shergotty (fragment A; [9]) and shergottite EETA 79001 (lithologies A and B; [10]) were also obtained. Each meteorite sample was pulverized to <45 microns, mixed with sucrose, and encapsulated in small plastic cylinders for Mossbauer spectral measurements at 4.2K and room temperature. Other experimental details are described elsewhere [1,2].

Results. Compiled in Figure 1 are the 4.2K Mossbauer spectra of suites of three of the shergottites (left panel) and the three nakhlites (right panel). The nakhlite spectra are complex due to the onset of magnetic ordering of Fe^{2+} ions in olivine [11] demonstrated previously [2,12] for olivine-rich Chassigny, Brachina, and ALHA 77005, the 4.2 K Mossbauer spectra of which are reproduced in Figure 2. Three of the olivine peaks at -4.2, +1.3 and +4.6 mm s^{-1} are particularly sensitive to variations of composition and temperature [11], requiring that the temperature be rigidly maintained at 4.2K during spectrum acquition. Figure 1 (right panel) shows that the 4.2K spectra of all three naklites resemble one another closely. Weak broad features at -7.8 and +8.7 mm s^{-1} attributed to Fe^{3+}-bearing phases are present in the spectra of all three nakhlites, including nanophase goethite + phyllosilicate assemblages comprising iddingsite [13] of preterrestrial origin [14,15]. The ferric features are particularly conspicuous in the spectrum of Lafayette and cannot be due entirely to fusion crust impurities. Overall, the spectrum profile of Lafayette more closely resembles that of Governador Valadares than Nakhla.

The shergottite spectra illustrated in Figure 1 (left panel) are dominated by absorption by Fe^{2+} ions in pyroxenes, the subtle differences of spectrum profiles reflecting differences of modal proportions of augite, low Ca pyroxenes and olivine [10,16]. The very weakly developed Fe^{3+} peaks around -7.8, -4.5 and +8.7 mm s^{-1} in Shergotty and Zagami are attributed to ~2% titanomagnetite reported in these meteorites [8]. The 4.2K spectrum profiles of the shergottites are clearly different from those of nakhlites (Figure 1, right) and chassignites illustrated in Figure 2.

The 4.2 K Mossbauer spectra of the olivine dominated achondrites assembled in Figure 2 show that ferric oxide peaks are particularly conspicuous in Brachina (found in South Australia in 1974) which is not, however, a SNC meteorite. Similar ferric oxide peaks are barely perceptable in Chassigny (which fell in France in 1815) and in ALHA 77005.

Discussion. The small but perceptible differences of Mossbauer spectral profiles between Lafayette and Nakhla indicate that they are separate meteorites. Whereas events relating to the fall of Nakhla in 1912 are well documented [4,7], details for Lafayette prior to 1931 (when it was first recognised as a meteorite in the collection at Purdue University) are ambiguous [3,5].

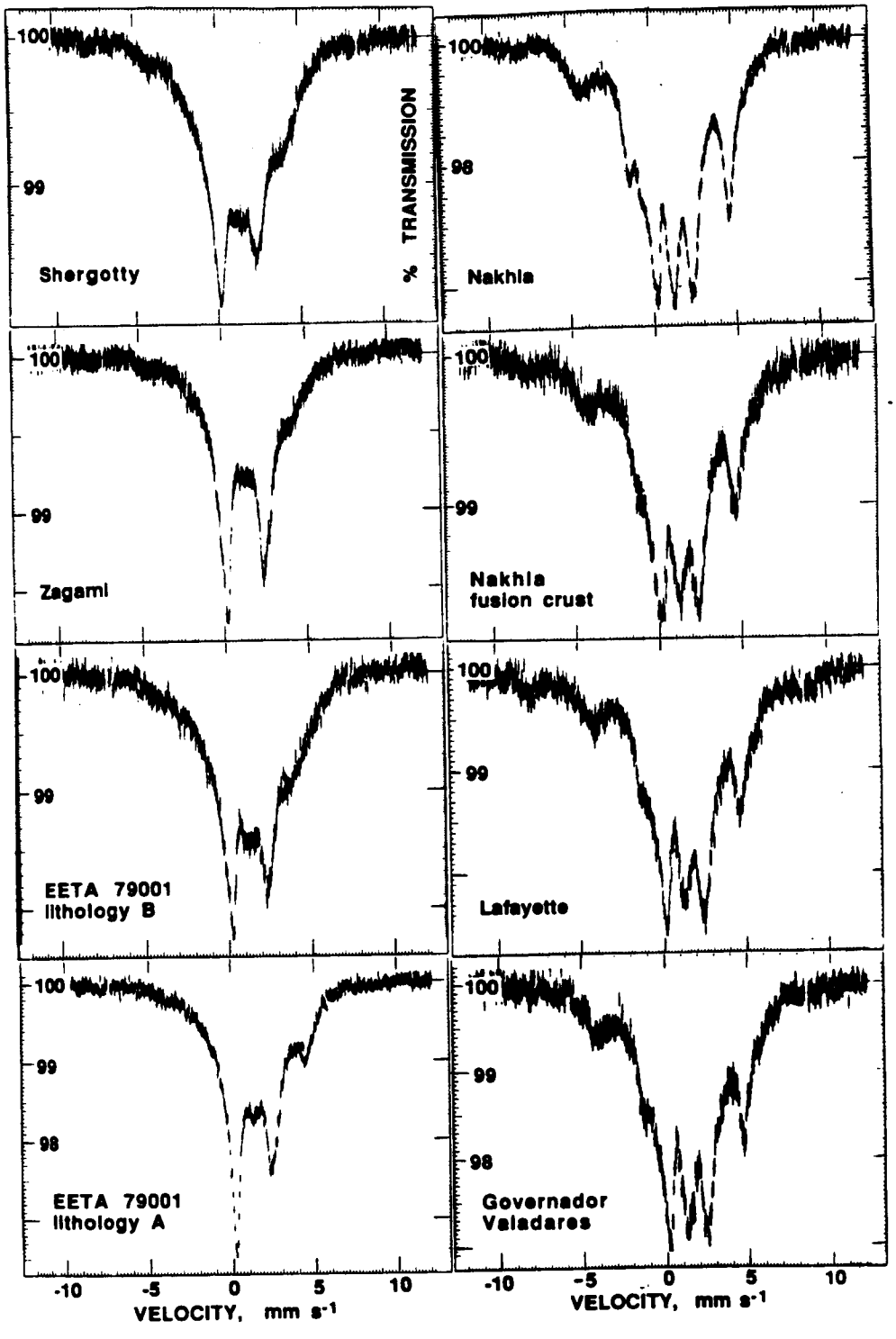

Figure 1. Mossbauer spectra of shergottites and nakhlites at 4.2 K. Left panel: shergotites; Right panel: naklites. Vertical dotted lines indicate the positions of the two outermost peaks of magnetic hyperfine sextets used to identify ferric oxides.

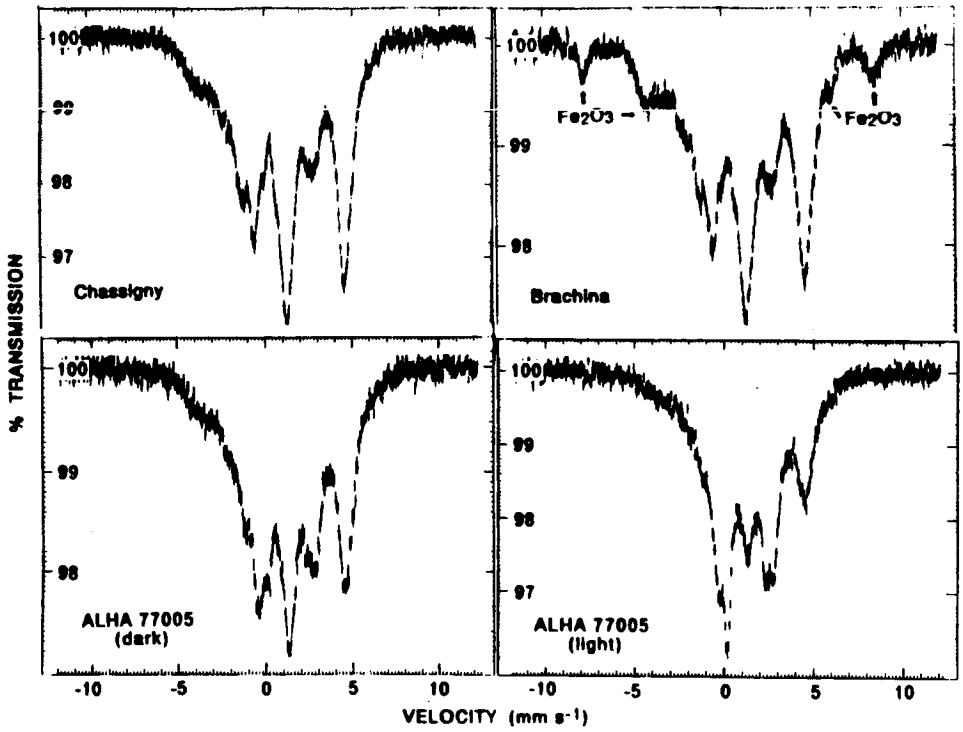

Figure 2. 4.2 K Mossbauer spectra of the olivine-dominated Brachina and SNC meteorites Chassigny and ALHA 77005

The two meteorites were once proposed to be identical [5] based on similarities of Xe isotopic data, bulk compositions, modal mineralogies, K-Ar and cosmic ray exposure ages [5,17,18] and Mossbauer spectra [2]. The discovery of the third nakhlite, Governador Valadares, with similar Mössbauer spectra and K-Ar and cosmic radiation ages to Nakhla and Lafayette [19], coupled with the fact that shergottites, themselves, also have virtually identical K-Ar and cosmic radiation ages, compositions, mineralogies [18,20] and Mossbauer spectra (Fig.1), would appear to dispell doubts that Lafayette is merely a mislabelled piece of Nakhla [18]. The three nakhlites may be genetically related, however, but their subsequent exposure histories in space and oxidative weathering on Earth have produced slight differences of Fe^{3+}/Fe^{2+} contents observed in the Mossbauer spectra. Alteration along cracks associated with shock metamorphism may be responsible for some of the FeOOH associated with iddingsite found in the three naklites [7,14]. However, chemical weathering on the surface of the Earth may have conributed to some of the FeOOH found in Governador Valadares. The high FeOOH content of Lafayette remains anomalous if, indeed, it was collected soon after falling to earth by the Purdue University student fishing near Lafayette [3].

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